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Sand/Granular Carbon Filtration Treatment System for Removing Aqueous Pesticide Residues from a Marine Toxicology Laboratory Effluent

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Flow-through toxicity tests using marine organisms can generate large volumes of contaminated sea water effluent which should be treated to remove the contaminants before being discharged into the environment. We have developed a sand filtration/activated carbon treatment system that removes a diversity of organophosphate, organochlorine and pyrethroid pesticide residues from these effluents. The sand filter removes from 60 to 97% of the chemicals by continuously filtering suspended particulates and associated chemicals as well as by facilitating partitioning of chemicals from water to organic material in the sand filter. Following sand filtration, effluent water slowly percolates through granular activated carbon. Overall, removal efficiencies exceed 90%. The organic material and associated chemicals are backwashed from the sand weekly, separated and concentrated by gravity and packaged for disposal. This system has been operating efficiently for over two years, processing a monthly average of 200,000 liters of sea water contaminated with 0.10 to 100 ug of pesticides ℓ^{-1}. Initial construction cost was $16,300.00.

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TECHNICAL NOTE

A SAND/GRANULAR CARBON FILTRATION TREATMENT SYSTEM FOR REMOVING AQUEOUS PESTICIDE RESIDUES FROM A MARINE TOXICOLOGY LABORATORY EFFLUENT*

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Abstract—Flow-through toxicity tests using marine organisms can generate large volumes of contaminated seawater effluent which should be treated to remove the contaminants before discharge into the environment. We have developed a sand filtration/carbon treatment system that removes from these effluents a diversity of organophosphate, organochlorine and pyrethroid pesticide residues down to their detection limit. The sand filter removed an average of 72% (range 4–99%) of the chemicals by continuously filtering suspended particulates and chemicals associated with the particulate. Following sand filtration, effluent water slowly percolates through granular carbon. Overall, organic removal efficiencies average 91% (range 24–99%). Initial construction cost was less than $20,000.

INTRODUCTION

The Federal Water Pollution Control Act, the Federal Insecticide, Fungicide and Rodenticide Act and the Toxic Substance Control Act state that the effect of substances on freshwater and marine organisms and their fate must be determined so that the environmental safety of these substances can be estimated. Effluents produced by these tests can be environmentally unacceptable and, if so, should be treated to remove any toxic chemicals prior to release into the environment. Since the toxicity of various classes of pesticides and the sensitivity of various marine organisms differ significantly, concentrations used in exposure water are diverse. Although the design of our toxicity tests and the requirements in standard operating procedures substantially limit the wastewater volume, the types and the concentrations of chemicals in the effluent, we believed effluent quality control was necessary. The types and concentrations of chemicals tested, and the fact that the monthly effluent volumes vary by relatively small volumes (100–1300 m^3) places unique design requirements on the treatment system.

Our experience with sand filtration demonstrated that selected pesticides associated with particulates in seawater could be removed; multiple passes through the filter improved removal efficiencies. Contaminants concentrated on organic matter were removed from the filter by backwashing the sand and collecting the waste backwash water. Therefore, we believed filtration with sand followed by carbon to polish the wastewater might prove effective for our particular treatment needs. Cleasby and Bauman's review (1979) of wastewater filtration design configuration also showed these to be useful media for filtration treatment.

Here we present a wastewater treatment facility that provides an efficient, low cost, versatile, and easily maintained process for removing $\mu g\,l^{-1}$ concentrations of pesticide residues from seawater and reduces the volume of contaminated material to a minimum for convenient packaging and disposal.

TREATMENT SYSTEM DESIGN AND OPERATION

The configuration of the system is shown in Fig. 1. Manufacturers and 1980 cost of components used in the system are listed in Table 1. However, we believe that comparable products from other manufacturers should work as well and be of similar cost.

The components of the treatment system (Fig. 1) are surrounded by a concrete wall 45 cm high to prevent accidental spills of wastewater from escaping the treatment area. The height of the wall increases to about 150 cm around the settling tank. A floor drain inside the treatment area is connected to the retention pond to remove spilled wastewater and pro-

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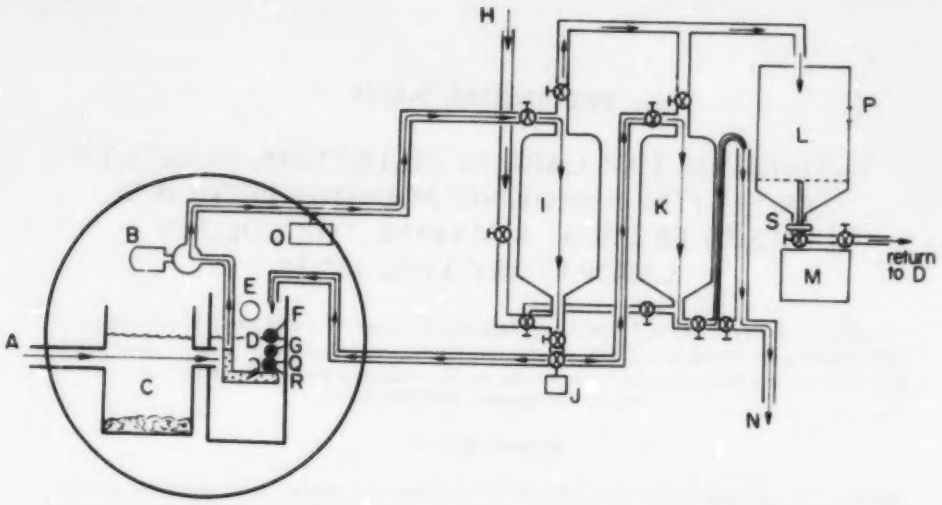

Fig. 1. Schematic of effluent treatment system. A—influent; B—pump; C—trap; D—pump reservoir; E—overflow pipe to emergency retention pond; F, G, Q, R—float switches; H—backwash water entrance; I—sand filter; J—electric solenoid; K—charcoal filter; L—settling tank; M—evaporation tank; N—effluent released to retention pond; O—flow monitor; P—float switch for automatic cut off of backwash; S—standpipe.

vide an environment for sorption and biodegradation to occur.

Float switches (Fig. 1, I, F, G, Q, R) in a 250 l. pump reservoir (Fig. 1, D) and Flip-Paks* form the electrical circuits that automatically control the treatment process. As wastewater effluent continuously fills the reservoir, it is recirculated by pump (B) from the reservoir (D) through the sand filter (I) and back to the reservoir. As this process is repeated organic material and associated toxicants are removed by the sand filter, causing the rate of water flow through the filter to decline. The flow rate is restored by backwashing organic particulates into a conical holding tank (L) where they concentrate by settling. When the effluent reaches a preselected upper level in the reservoir, a float switch (F) activates the solenoid valve (J), causing wastewater being pumped through the sand filter (I) to be diverted to the carbon filter (K). Wastewater in the carbon filter is displaced into the retention pond (N) in 100-l. increments with water from the sand filter. When the volume of wastewater in the reservoir is reduced by 100 l., the second float switch (G) reactivates the solenoid valve (J). The pump continuously circulates water through the sand filter (I) to the pump reservoir, allowing the effluent to be recirculated 10–20 times through the sand filter before it is passed onto the carbon filter (K). If the water level falls below the pump intake, a float switch (Q) turns off the pump to prevent loss of prime and overheating. Another float switch (R) restarts the pump (B) when the water level rises above the intake.

*Mention of trade names or commercial products does not constitute endorcement by the U.S. Environmental Protection Agency.

Filter configuration

The sand filter and carbon filter housings are welded steel, 1.7 m high and 1.2 m dia., designed to withstand 70 kg cm^{-2} (100 psi). Approximate dimensions and volumes of layered filter media: 0.62 m^3 fine sand (0.5 mm), 0.11 m^3 medium sand (0.8 mm), 0.11 m^3 fine graded gravel (0.32–0.64 cm), 0.11 m^3

Table 1. Manufacturer and cost of the major components in the treatment system (letter in parentheses identifies component in Fig. 1)

Component	Manufacturer	Cost ($)
Filter tanks (I, K) with media	Water Purification Systems, Inc. 3451 East 26th Street Los Angeles, CA 90023	9984
Settling tank (L)	Wallace Murray Corporation Fiberglass Products P.O. Box 510 E. Jones St Wilson, NC 27839	4636
Pump (B) (model 1.5 HE19EL)	ITT Marlow P.O. Box 200 445 Godwin Avenue Midland Park, NJ 07432	1575
Paddle wheel flow sensor and meter	Signet Scientific 3401 Aerojet Avenue El Monte, CA 91731	2515
Electric valve actuator (series 87) and CPVC ball valve (J)	ASAHI/America 425 Riverside Avenue Medford, MA 02155	470
Fluid flow switches model LS-1800 (F, G, Q, R, P) model 28196 flip-paks	Transamerica Delaval, Inc. GEMS Sensor Division Cowles Road Plainville, CT 06062	160
Evaporation tank (M)	Red Ewald Inc. P.O. Box 519 Karnes, TX 78118	300

medium graded gravel (0.64–0.96 cm), 0.14 m^3 medium graded gravel (0.95–1.9 cm) and 0.085 m^3 coarse gravel (1.9–3.8 cm). The carbon filter duplicates the sand filter except that the top layer of sand is covered by 0.26 m^3 of anthrafilt carbon (1.50 uniformity coefficient, effective size 1.13, 1.4–2.3 mm with not more than 18% by weight larger than 2.3 mm and not more than 18% by weight less than 1.4 mm). Carbon must be free of iron, sulfides, clay, shale and extraneous dirt and excessive dust.

Wastewater is pumped through the filter at a peak flow rate of 0.32 $m^3 min^{-1}$ as measured by a paddle wheel [Signet Flosensor*] (Fig. 1, O). As suspended particulates are deposited on the sand, flow rate declines to 0.10 $m^3 min^{-1}$ after 7–10 days. Initial operating pressure is 0.70 kg cm^{-2} (10 psi). When the resistance across the sand filter increases the operating pressure to 1.4 kg cm^{-2} (20 psi), the filter is backwashed with 15 m^3 of freshwater at 0.70 kg cm^{-2} (10 psi). Backwashing usually takes 30 min and is performed weekly. Backwashing restores the sand filter to its initial flow rate and operating pressure.

The carbon receives relatively clean wastewater from the sand filter. The external standpipe connected to the filter's drain (Fig. 1, S) prevents water from siphoning out and allows only the volume of water pumped onto the carbon filter to pass from the filter into the outdoor retention pond. Residence time in the carbon filter is from 20 to 45 min as effluent flow from the laboratory varies from 0.3 to 1 $m^3 h^{-1}$. Although changes in effluent flow cause the number of times wastewater passes through the sand filter and the residence time in the carbon filter to vary, removal efficiency of the system was the same for all flow rates.

Water from the treatment system enters an outdoor retention pond used as a precaution in case the system cannot treat the contaminants and for collection of effluent during backwashing or repair. The pond is approx. 15 × 21 × 2 m deep and contains about 300 m^3 of seawater. Half-life of water that enters this pond and percolates through the soil is approx. 3 months (determined with fluorescein dye studies), i.e. greater than the half-life of most of the chemicals tested in our laboratory (Schimmel *et al.*, 1983).

RESULTS

During tests of filter efficiencies, several pesticides (organochlorine, organophosphate, carbamate or pyrethroid) usually were present in wastewater effluents from toxicity tests. Most samples of wastewater exiting the treatment system during 1980, 1981 and 1982 did not contain detectable residues of these pesticides because influent concentrations for most sublethal toxicity tests were typically less than 20 $\mu g l^{-1}$ and were diluted further by wastewater from other tests. The pyrethroids, fenvalerate and permethrin, were particularly difficult to detect because test concentrations usually ranged below analytical method detection limits. Compounds within these classes and their concentrations in tests continually changed over time; consequently, prediction of the time for best detection was difficult, and removal efficiencies for some pesticides were determined occasionally or not at all during the weekly analyses of influent wastewater and post-filtration effluent.

Only chemical analyses with detectable residues were used to calculate removal efficiencies of the filters for various classes of pesticides and several other organic chemicals (Table 2). Average removal efficiencies in Table 2 represent minimum efficiencies because many of the pesticides were removed to concentrations less than our limits of chemical detection.

Average percentage removal efficiencies of the total treatment system for pyrethroids, organophosphates and organochlorines were 79, 92 and 96%, respectively. Percentages of pyrethroid, organophosphate and organochlorine residues removed by sand filtration prior to carbon filtration were 79, 72 and 74%, respectively. All residues of the pyrethroids were removed down to detection limits.

Nonfilterable solids recovered by backwashing the sand filter during the first year were collected in three 5–20 l. containers. Only chlorpyrifos has been detected; concentrations ranged from 0.29 to 3.3 $\mu g g^{-1}$ dry wt. Percentage moisture was 82% and percentage organic matter was 15% for solids and varied little among samples.

DISCUSSION

Although the system has continually performed satisfactorily, several improvements in the filter design could make maintenance more efficient and easier: (1) larger openings in the lower portion of the filter housing would save time and labor when replacing the medium (it is pumped from an oval opening in the top); (2) the bottom distribution should be altered to allow higher flow rates of water for backwashing (this deficiency is now overcome by using compressed air to increase turbulence in the sand during backwashing); (3) the inner steel housing is susceptible to corrosion in the salt environment, therefore a 100 mm thick PVC coating was added to prevent corrosion (fiberglass may be adequate construction material). A wastewater emergency retention area may be useful as a safety precaution in the event of an accidental spill or system malfunction, such as pump or power failures.

Periodic injections of chemical residues into the system may be desirable to determine its response to new classes of chemicals and to ensure quality control during extended periods of operation, particularly if influent residue concentrations are near detection limits.

This treatment system efficiently removes a variety of aqueous pesticide residues from seawater. The

Table 2. Number of samples where compound was detected, concentrations of compounds in effluents from the laboratory and filters, and removal efficiencies of filters during 1980, 1981 and 1982 (N = number of samples; concentrations and detection limits in $\mu g l^{-1}$; efficiencies are percentage of pesticides in laboratory effluent removed down to detection limit)

		Laboratory effluent			Sand filter effluent			Carbon filter effluent			
Compound	Detection limit*	N	Mean	Range	N	Range	Removal efficiency (%)	N	Range	Removal efficiency (%)	Total efficiency (%)
AC 217,300	0.20	1	0.84	—	0	—	76	0	—	—	76
AC 222,705	0.15	1	5.3	—	0	—	97	0	—	—	97
Benthiocarb	0.50	6	42	0.66–120	4	24–28	4–77	0	—	3–34	24–99
Carbophenothion	0.15	10	9.3	0.25–40	7	0.11–1.6	80–99	2	0.40	1–9	80–99
Chlorpyrifos	0.015	15	5.8	0.19–42	10	0.049–16	29–99	7	0.034–1.7	11–64	86–99
DEF	0.010	8	0.12	0.060–0.17	6	0.035–0.12	45–86	0	—	0–50	83–95
Dibutyl phthalate	0.20	3	380	1.7–620	2	0–260	58–99	1	1.8	14–41	94–99
Endosulfan	0.010	4	5.4	0.16–16	2	0.055–1.8	74–89	1	0.11	10	94–99
Endrin	0.0040	4	0.18	0.066–0.27	4	0.024–0.041	64–87	0	—	12–30	94–99
Fenvalerate	0.15	2	0.35	0.29–0.40	0	—	52–63	0	—	—	52–63
Methomyl	0.20	1	43	—	1	17	61	0	—	38	99
Pentachlorobenzene	0.0050	2	0.41	0.10–0.71	2	0.065–0.46	36–40	1	0.022	63–83	83–99
Permethrin	0.25	3	2.3	1.2–3.8	1	0.47	79–94	0	—	94	79–94
Trifluralin	0.020	2	0.085	0.080–0.089	1	0.062	53–75	0	—	25	75–78

*1 l. of seawater concentrated to 2.0 ml.

sand filter removes most of these residues associated with nonfilterable solids prior to carbon filtration. The volume of contaminated waste is limited to the solids trapped by sand filtration and the expended carbon. This design is versatile, economic to build and maintain, and may also be applied to freshwater research facilities. It can accommodate monthly flows ranging up to 2000 m^3 and, when necessary, this capacity can be substantially increased with minor system modifications.

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